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Surface Vessel Bilgewater/Oil Water Separator

Section 4.0 – LHD 1 Class: Conventional Steam Propulsion Amphibious Assault Vessels

2003

SECTION 4.0 – LHD 1 CLASS

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4.0 LHD 1 CLASS

The USS WASP Class (LHD 1) was selected to represent the group of vessels that are powered by conventional steam propulsion. The LHD 1 is the largest class of amphibious assault vessels. LHD 1 Class vessels operate 175 days annually beyond 12 nautical miles (nm) of shore (Navy and EPA, 2003). The total volume of bilgewater generated within 12 nm is calculated by adding the volume of bilgewater generated in port to the volume generated while operating within 12 nm (e.g., steaming within 12 nm that occurs while transiting out to 12 nm). LHD 1 Class vessels spend approximately 190 days annually within 12 nm of shore; 185 of those days are spent in port and 5 cumulative days are spent in transit (Navy and EPA, 2003). The in-port bilgewater generation rate for each vessel in this class is 6,250 gallons per day (gpd), and the underway (both transiting and beyond 12 nm) rate is 25,000 gpd (Navy and EPA, 2003). Each vessel in this class generates approximately 1,281,000 gallons of bilgewater while within 12 nm and approximately 4,375,000 gallons of bilgewater beyond 12nm annually.

Bilgewater generated within 12 nm:

$$\frac{185\text{ days (pierside)}}{\text{yr}} \bullet \frac{6{,}250\text{ gal}}{\text{day}} + \frac{5\text{ days (underway)}}{\text{yr}} \bullet \frac{25{,}000\text{ gal}}{\text{day}} = 1{,}281{,}000\text{ gal/yr}$$

Bilgewater generated beyond 12 nm:

$$\frac{175\text{ days (underway)}}{\text{yr}} \bullet \frac{25{,}000\text{ gal}}{\text{day}} = 4{,}375{,}000\text{ gal/yr}$$

LHD 1 Class vessels are equipped with two 50 gallons per minute (gpm) gravity coalescence type oil water separators (OWSs) (Facet model C-50). Consequently, this option is the current marine pollution control device (MPCD). Details related to the application of OWSs on-board LHD 1 Class vessels are outlined in the sections below. LHD 1 Class vessels use one 90-gpm pump to offload oily waste and one 54-gpm pump to offload waste oil to shore facilities.

Where appropriate, the current MPCD was used to determine the operational capacities and other parameters used to evaluate each of the MPCDs in the feasibility analysis. The following MPCDs are evaluated for LHD 1 Class vessels: gravity coalescence, centrifuge, collection, holding, and transfer (CHT), evaporation, hydrocyclone, *in situ* biological treatment, oil absorbing sock, filter media, and membrane filtration.

4.1 GRAVITY COALESCENCE

The following sections discuss the feasibility and cost impacts of installing and operating gravity coalescers on-board LHD 1 Class vessels.

4.1.1 Practicability and Operational Impact Analysis

This section describes the analyses of specific feasibility criteria relative to the physical characteristics and operational requirements of gravity coalescence units.

4.1.1.1 Space and Weight

As described in Section 4.0, the analysis of gravity coalescence will include two 50-gpm gravity coalescence units (C-50) and one 54-gpm pump. The gravity coalescence OWS units on-board these vessels are intended for single-deck operation and are commonly installed in main or auxiliary machinery spaces, in the vicinity of the oily waste holding tank (OWHT). Table 4-1 provides the space and weight for the C-50.

Table 4-1. C-50 Specifications (LHD 1 Class)

Physical Properties	Number of Units	Capacity	Size (ft.) L x W x H	Maintenance Envelope (ft.)	Volume (ft^3)	Weight (lbs.) Dry/Flooded
Per unit	1	50 gpm	6 x 2.7 x 5	10 x 4.7 x 7	81	2400/4500
Total (To achieve required processing capacity)	2	100 gpm	-	-	162	4800/9000

Clearance is required above the OWS tank assembly to mount chain falls for removal of the tank cover. The envelope for installation and maintenance remain the same.

4.1.1.2 Personnel/Equipment Safety

There are no unusual personnel or equipment safety hazards associated with gravity coalescence units. Other than wearing standard personal protective equipment (e.g., rubber gloves/boots and safety glasses/goggles) during maintenance activities, no special devices or precautions are necessary. Any hazardous materials required for operation and maintenance (e.g., oil and grease) are minimal in quantity and authorized for use on-board vessels of the Armed Forces. Standard afloat control and management procedures are adequate for use and disposal of the material. While gravity coalescence units require electrical power, existing standard shipboard safety procedures for handling electrical equipment are adequate to protect personnel safety.

4.1.1.3 Mission Capabilities

The use of C-50 gravity coalescence type OWSs on LHD 1 Class vessels has not resulted in any impact on ship's signature, war fighting capabilities, mobility, or any mission critical systems or operations.

4.1.1.4 Personnel Impact

The C-50 separators operate in automatic mode but require general supervision while the units are operating. Based on an MPCD rated capacity of 100 gpm (for both units) and the 1,281,000 gallons of bilgewater generated annually within 12 nm, the number of hours each gravity coalescer is operated annually within 12 nm is approximately 214 hours.

$$\frac{1{,}281{,}000 \text{ gal}}{\text{yr}} \bullet \frac{\text{min}}{100 \text{ gal}} \bullet \frac{\text{hr}}{60 \text{ min}} = 214 \text{ hrs/yr}$$

Based on operational experience, the time required per year to supervise the operation of a C-50 separator is approximately 0.25 hours (15 minutes) for every two hours the unit operates. The supervisory labor requirement of 15 minutes for every two hours of operation is based on the assumption that although the unit is automatic, a crewmember will be assigned to supervise the operation of multiple pieces of equipment at once. Therefore, the time required to oversee both C-50 units is assumed to be the same as for a single unit. Based on the annual operating requirement of 214 hours, the annual labor requirement associated with the operation of both gravity coalescence units within 12 nm is 27 hours as calculated below:

$$\frac{214\ \text{hr}}{\text{yr}} \bullet \frac{0.25\ \text{hrs labor}}{2\ \text{hrs}} = 27\ \text{hrs labor/yr}$$

In addition, the waste oil removed from the bilgewater must be transferred to a shore facility. This transfer requires three crewmembers per event. One crewmember is required to operate the waste oil transfer pump and associated valves and hull connections. A second crewmember is required to oversee the connection of transfer hoses for the offloading vessel. A third crewmember oversees the connection of transfer hoses for the receiving vessel or facility. The two crewmembers overseeing the transfer hose connections stand by the hose connections in case the connections separate. The two crewmembers also ensure that appropriate precautions are taken to prevent oil spills. During waste oil transfer activities, two-way voice communication must be established between the three crewmembers overseeing the oil transfer (Navy, 2002). The labor hours associated with transferring the waste oil produced within 12 nm of shore by a gravity coalescence unit on the LHD 1 are calculated by dividing the waste oil volume (1 percent of the annual bilgewater volume generated while operating within 12 nm of shore) by the waste oil pump rate (54 gpm) and multiplying by the number (three) of crewmembers.

$$\frac{12{,}810\ \text{gal}}{\text{yr}} \bullet \frac{\text{min}}{54\ \text{gal}} \bullet \frac{\text{hr}}{60\ \text{min}} \bullet \frac{3\ \text{hrs labor}}{\text{hr}} = 12\ \text{hrs labor/yr}$$

The combined annual labor associated with the operational oversight of both gravity coalescence units within 12 nm and the transfer of waste oil generated within 12 nm on an LHD 1 Class vessel is 39 hours.

The total labor requirement associated with gravity coalescence operation beyond 12 nm includes MPCD operator oversight (i.e., 15 minutes for every two hours of equipment operation) and labor required to oversee the offloading of waste oil to shore attributable to vessel operation beyond 12 nm. The annual labor requirement associated with operating this MPCD beyond 12 nm is calculated using the same methodology used to calculate the annual labor requirement within 12 nm. The approximate volume (i.e. 4,375,000 gal) of bilgewater generated beyond 12 nm and resultant volume (i.e. 43,750 gal) of waste oil that requires offloading to shore are based on the LHD 1 Class vessel underway bilgewater generation rate of 25,000 gpd. The underway generation rate is multiplied by the number of days (175 days) spent beyond 12 nm. Hours of MPCD operation and annual labor requirements are presented below.

Hours of MPCD operation beyond 12 nm:

$$\frac{4{,}375{,}000 \text{ gal}}{\text{yr}} \bullet \frac{\text{min}}{100 \text{ gal}} \bullet \frac{\text{hr}}{60 \text{ min}} = 729 \text{ hrs/yr}$$

Labor requirement for MPCD operator oversight:

$$\frac{729 \text{ hrs}}{\text{yr}} \bullet \frac{0.25 \text{ hrs labor}}{2 \text{ hrs}} = 91 \text{ hrs labor/yr}$$

Labor requirement for offloading waste oil:

$$\frac{43{,}750 \text{ gal}}{\text{yr}} \bullet \frac{\text{min}}{54 \text{ gal}} \bullet \frac{\text{hr}}{60 \text{ min}} \bullet \frac{3 \text{ hrs labor}}{\text{hr}} = 41 \text{ hrs labor/yr}$$

Total MPCD operator labor and waste oil offloading oversight associated with the operation of this vessel class beyond 12 nm is 132 hrs/yr.

Annually, each C-50 requires approximately 173.4 personnel hours of time-based maintenance, 0 personnel hours of condition-based maintenance, within 12 nm, and 0 personnel hours of condition-based maintenance beyond 12 nm. Table 4-2 and Table 4-3 summarize the time-based maintenance and the condition-based maintenance requirements, respectively, for one C-50 separator.

Table 4-2. C-50 Time-Based Maintenance (LHD 1 Class)

Maintenance Activity	Maintenance Time (hours)	Frequency	Annualized Maintenance Time (hours)
Check Pressure Gage Indications	0.3	1 week	15.6
Check Valve Actuator Cam Adjustments	0.3	1 week	15.6
Check Adjustment of Pressure Reducing Valve	0.3	1 month	3.6
Clean and Inspect Electrical Control Panel	1.6	3 months	6.4
Inspect and Lubricate Swing Check Valve	1.4	3 months	5.6
Lubricate Solenoid Valve Linkage	0.2	3 months	0.8
Clean and Inspect Conductance Type Level Sensor	0.5	3 months	2
Clean and Inspect OWS Tank	16	6 months	32
Lubricate Simplex Strainer	0.3	6 months	0.6
Test Relief Valve	0.2	6 months	0.4
Clean and Inspect Flow Totalizer	1.0	6 months	2
Clean and Inspect Motorized Ball Valve(s)	1.5	12 months	1.5
Test Operate Pumps	0.6	12 months	0.6
Total Annual Labor per unit			86.7

Maintenance Activity	Maintenance Time (hours)	Frequency	Annualized Maintenance Time (hours)
Total Annual Labor per vessel			173.4

Table 4-3. C-50 Condition-Based Maintenance (LHD 1 Class)

Maintenance Activity	Maintenance Time (hours)	Frequency (based on hours of MPCD operation)	Annualized Maintenance Hours (based on operation hours within 12 nm)	Annualized Maintenance Hours (based on operation hours beyond 12 nm)
N/A	0	0	0	0
Total Annualized Hours	-	-	0	0

Table 4-4 provides the annual labor hours required to operate and maintain the C-50 units.

Table 4-4. Gravity Coalescence Annual Labor Hours (LHD 1 Class)

	Gravity Coalescer (C-50)
Operator Hours Within 12 nm	39
Operator Hours Beyond of 12 nm	132
Condition-based Maintenance Within 12 nm	0
Condition-based Maintenance Beyond 12 nm	0
Time-based Maintenance	173.4
Total Time	344

4.1.1.5 Consumables, Repair Parts, and Tools

The C-50 units installed on LHD 1 Class vessels do not require consumables. No special tools are required for the operation or maintenance of these units.

4.1.1.6 Interface Requirements

Table 4-5 summarizes specific system interface requirements associated with the C-50 OWS units.

Table 4-5. C-50 Interface Requirements (LHD 1 Class)

Shipboard System	C-50 Interface Requirements
Electrical Power	3 hp (2.2 kW), 440V/3Ph/60Hz
Potable Water	May be used for priming, 25 psi max
Seawater	Requires 25 psi seawater pressure
Drainage	Gravity drain to OWHT

4.1.1.7 Control System Requirements

The gravity coalescence units installed on-board LHD 1 Class vessels are designed to operate in either automatic or manual mode. Automatic operation is the normal operating mode. When placed in the automatic mode, activation of the units is controlled by tank level switches, which are installed in the OWHT. One level switch starts the unit(s) when the liquid level in the tank reaches a pre-set level. When the liquid level in the OWHT drops to a pre-set level, a second level switch signals the unit(s) to shut down. C-50 units have a flow sensor that secures the system if the pump loses suction and a remote alarm/indicator panel that allows shipboard personnel to monitor the operating status of the units while in the automatic mode of operation. The remote alarm/indicator contains visual indicators that allow operating personnel to monitor the overall status of the system and an audible alarm that warns of system malfunction.

In addition, C-50 units are equipped with an oil content monitor (OCM) to measure the oil content of OWS effluent. If the OCM detects an oil concentration greater than the predetermined desired concentration, the OCM will redirect the effluent back to the OWHT to be retreated by the OWS.

4.1.1.8 Other/Unique Characteristics

No other/unique characteristics have been identified with respect to this MPCD option.

4.1.2 Cost Analysis

The following cost data and calculations are provided to allow the reader to compare relative costs associated with a gravity coalescence system on an LHD 1 Class vessel.

4.1.2.1 Initial Cost

There are no initial costs associated with gravity coalescence on an LHD 1 Class vessel because the equipment is in place as described above.

4.1.2.2 Recurring Cost

Personnel Labor Within 12 nm

This MPCD requires 213 personnel hours per year for operation, condition-based maintenance, and time-based maintenance within 12 nm, as explained under Section 4.1.1.4. The number of annual labor hours multiplied by the $22.64 hourly MPCD operator labor rate produces the first operating year recurring labor cost within 12 nm.

$$\frac{\$22.64}{\text{hr}} \bullet \frac{213\text{ hrs}}{\text{yr}} = \$4{,}820/\text{yr (inside 12 nm)}$$

Personnel Labor Beyond 12 nm

This MPCD requires 132 personnel hours per year for operation and condition-based maintenance beyond 12 nm, as explained under Section 4.1.1.4. The annual labor cost associated with operating this MPCD beyond 12 nm is calculated using the same hourly labor rate used to calculate the annual labor cost within 12 nm, as shown below.

$$\frac{\$22.64}{\text{hr}} \bullet \frac{132\ \text{hrs}}{\text{yr}} = \$2{,}980/\text{yr (outside 12 nm)}$$

The labor required to transfer waste oil generated by the gravity coalescence system to a disposal activity is included in the above labor cost estimates. As explained in Section 1.1.2, the disposal activity is assumed to dispose the waste oil at no charge for these vessels.

Table 4-6 summarizes the annual recurring costs for a gravity coalescence system on-board an LHD 1 Class vessel.

Table 4-6. Annual Recurring Costs for Gravity Coalescence (LHD 1 Class)

Vessel Operating Parameter	Disposal Cost Used	Annual Recurring Cost ($K)
Within 12 nm	Navy	4.82
Beyond 12 nm	Navy	2.98

4.1.2.3 Total Ownership Cost (TOC)

Table 4-7 summarizes the TOC and annualized cost over a 15-year lifecycle of a gravity coalescence system on an LHD 1 Class vessel.

Table 4-7. TOC for Gravity Coalescence (LHD 1 Class)

Cost ($K)	Vessel Operation Within 12 nm	Vessel Operation Within + Beyond 12 nm
Total Initial	0.00	0.00
Total Recurring	53.5	86.7
TOC (15-yr lifecycle)	53.5	86.7
Annualized	4.5	7.4

4.2 CENTRIFUGE

The following sections discuss the feasibility and cost impacts of installing and operating a centrifuge on-board an LHD 1 Class vessel.

4.2.1 Practicability and Operational Impact Analysis

This section analyzes specific feasibility criteria relative to the physical characteristics and operational requirements of centrifuges.

4.2.1.1 Space and Weight

Two 50-gpm centrifuge units (Westfalia model WSC 50), for a total processing capacity of 100 gpm, are proposed in this analysis. The units are manufactured by a major supplier of centrifuges used in the marine industry and are representative in space, weight, and power requirements of centrifuges with similar processing capacities. Table 4-8 provides the space and weight for the centrifuge, which comes as a complete modular unit (includes one 50-gpm centrifuge and heater).

Table 4-8. Centrifuge Specifications (LHD 1 Class)

Physical Properties	Number of Units	Capacity	Size (ft.) L x W x H	Maintenance Envelope (ft.)	Volume (ft^3)	Weight (lbs.) Dry/Flooded
Per unit	1	50 gpm	6 x 8 x 8.2	7.75 x 10 x 9.2	393.6	3150/3500
Total (To achieve required processing capacity)	2	100 gpm	-	-	787.2	6300/7000

The centrifuge is designed for single deck operation. The two existing OWS units would be removed and replaced with the two centrifuge units. Installation of these centrifuges will not result in space or weight impacts. However, based upon a ship check of LHD 4 (an LHD 1 Class vessel), an existing 10-inch steam line, a chilled water line, electrical cables and ducting would have to be relocated to provide height clearance for the new modules.

4.2.1.2 Personnel/Equipment Safety

Other than wearing standard personal protective equipment (e.g., rubber gloves/boots and safety glasses/goggles) during maintenance activities, no special devices or precautions are necessary. Any hazardous materials (e.g., oil and grease) required for operation and maintenance are minimal in quantity and authorized for use. Standard afloat control and management procedures are adequate for use and disposal of the material. While centrifuges require electrical power, existing standard shipboard safety procedures for handling electrical equipment are adequate to protect personnel safety. Integral heaters provided as part of the centrifuge module preheat the bilgewater to 90 - 95^{o}C. However, the heater and associated piping are well insulated and will not pose a burn hazard to personnel (Donohue, 1999).

4.2.1.3 Mission Capabilities

The installation and operation of centrifuges on LHD 1 Class vessels are not expected to have an impact on ship's signature, war fighting capabilities, mobility, or on any mission critical systems or operations.

4.2.1.4 Personnel Impact

The WSC-50 centrifuge runs in automatic mode, but requires general supervision while the unit is operating. Based on an MPCD rated capacity of 100 gpm (for both units) and approximately 1,281,000 gallons of bilgewater generated annually within 12 nm, the number of hours each centrifuge is operated annually within 12 nm is 214 hours.

$$\frac{1{,}281{,}000\text{ gal}}{\text{yr}} \bullet \frac{\text{min}}{100\text{ gal}} \bullet \frac{\text{hr}}{60\text{ min}} = 214\text{ hrs/yr}$$

The labor requirement for general oversight of the centrifuge system was calculated as 0.25 hours (15 minutes) for every two hours of operation. The supervisory labor requirement of 15 minutes for every two hours of operation is based on the assumption that although the units are automatic, a crewmember will be assigned to general oversight of multiple pieces of equipment at once. Therefore, the time required to oversee both units is assumed to be the same as one unit. Based on the annual operating requirement of 214 hours, the annual labor requirement associated with the operation of both centrifuges within 12 nm is 27 hours as calculated below:

$$\frac{214\text{ hrs}}{\text{yr}} \bullet \frac{0.25\text{ hr labor}}{2\text{ hrs operation}} = 27\text{ hrs labor/yr}$$

In addition, the waste oil removed from the bilgewater must be transferred to a shore facility. This transfer requires three crewmembers per event as described under Section 4.1.1.4. The labor hours associated with transferring the waste oil produced within 12 nm of shore by centrifuges on LHD 1 Class vessels are calculated by dividing the waste oil volume (1 percent of the annual volume of bilgewater generated while operating within 12 nm of shore) by the waste oil pump rate (54 gpm) and multiplying by the number (three) of crewmembers.

$$\frac{12{,}810\text{ gal}}{\text{yr}} \bullet \frac{\text{min}}{54\text{ gal}} \bullet \frac{\text{hr}}{60\text{ min}} \bullet \frac{3\text{ hrs labor}}{\text{hr}} = 12\text{ hrs labor/yr}$$

The combined annual labor associated with the operational oversight of both centrifuge modules within 12 nm and transfer of waste oil generated within 12 nm on an LHD 1 Class vessel is 39 hours.

The total labor requirement associated with vessel operation beyond 12 nm includes MPCD operator oversight (i.e., 15 minutes for every two hours of equipment operation) and labor required to oversee the offloading of waste oil to shore attributable to vessel operation beyond 12 nm. The annual labor requirement associated with operating this MPCD beyond 12 nm is calculated using the same methodology used to calculate the annual labor requirement within 12 nm. Hours of MPCD operation and annual labor requirements are presented below.

Hours of MPCD operation beyond 12 nm:

$$\frac{4{,}375{,}000\text{ gal}}{\text{yr}} \bullet \frac{\text{min}}{100\text{ gal}} \bullet \frac{\text{hr}}{60\text{ min}} = 729\text{ hrs/yr}$$

Labor requirement for MPCD operator oversight:

$$\frac{729\text{ hrs}}{\text{yr}} \bullet \frac{0.25\text{ hrs labor}}{2\text{ hrs}} = 91\text{ hrs labor/yr}$$

Labor requirement for offloading waste oil:

$$\frac{43{,}750\text{ gal}}{\text{yr}} \bullet \frac{\text{min}}{54\text{ gal}} \bullet \frac{\text{hr}}{60\text{ min}} \bullet \frac{3\text{ hrs labor}}{\text{hr}} = 41\text{ hrs labor/yr}$$

Total MPCD operator labor and waste oil offloading oversight associated with the operation of two WSC-50 centrifuge modules on LHD 1 Class vessel beyond 12 nm is 132 hrs/yr.

Annually, each WSC-50 requires approximately 20.75 personnel hours of time-based maintenance, 0 personnel hours of condition-based maintenance within 12 nm, and 0 personnel hours of condition-based maintenance beyond 12 nm. Table 4-9 and Table 4-10 summarize the time-based maintenance and the condition-based maintenance requirements, respectively, for one WSC-50 centrifuge module.

Table 4-9. WSC-50 Time-Based Maintenance (LHD 1 Class)

Maintenance Activity	Maintenance Time (hours)	Frequency	Annualized Maintenance Time (hours)
Change gear case oil.	1	6 months	2
Remove, clean, and grease bowl lock ring, and re-install it.	1	6 months	2
Grease motor bearings.	0.25	See manuf.* Recomm.	0.25
Inspect and clean bowl: Remove bowl top. Clean sludge space and disks as required. If the bowl is removed during this procedure, ensure that the spindle cone and bowl nave is clean, dry, and free of grease.	2	3 months	8
Check starting time. Check thickness of clutch shoe linings. Replace as necessary.	0.25	6 months	0.5
Check thickness of brake lining. Replace as necessary.	0.5	12 months	0.5
Check foundation bolts for proper tensioning. Check all readily accessible equipment bolts and fasteners for proper tension.	0.5	12 months	0.5
Check shock mounts for cracks, peeling of rubber, or any distortions. Replace as necessary.	0.25	12 months	0.25
Check to ensure that a clearance of 3 mm between the decelerator unit and ship's foundation is correct.	0.25	12 months	0.25
Replace Ball bearings on spindle	1	12 months	1
Replace Ball bearings on worm wheel shaft	1	6 months	2
Check pump strainer. Clean as required.	0.25	6 months	0.5
Check water strainer(s). Clean as required.	0.25	6 months	0.5
Check to make sure operating water feeding device is not plugged.	0.25	6 months	0.5

Maintenance Activity	Maintenance Time (hours)	Frequency	Annualized Maintenance Time (hours)
Check and tighten system hardware including all foundations	1	12 months	1
Check motor winding resistance.	0.5	12 months	0.5
Check operation of pressure switch. Repair or replace as required.	0.25	6 months	0.5
Total Annual Labor per unit			20.75
Total Annual Labor per vessel			41.5

** For calculations it was assumed that the condition-based maintenance was performed annually.*

Table 4-10. WSC-50 Condition-Based Maintenance (LHD 1 Class)

Maintenance Activity	Maintenance Time (hours)	Frequency (based on hours of MPCD operation)	Annualized Maintenance Hours (based on operation hours within 12 nm)	Annualized Maintenance Hours (based on operation hours beyond 12 nm)
None	0	0	0	0
Total Annualized Hours	-	-	0	0

Table 4-11 provides the annual labor hours required for two WSC-50 Centrifuges.

Table 4-11. Centrifuge Annual Labor Hours (LHD 1 Class)

	MPCD Option: WSC-50 Centrifuge
Operator Hours Within 12 nm	39
Operator Hours Beyond of 12 nm	132
Condition-based Maintenance Within 12 nm	0
Condition-based Maintenance Beyond 12 nm	0
Time-based Maintenance	41.5
Total Time	212

4.2.1.5 Consumables, Repair Parts, and Tools

Centrifuges require consumables, repair parts, and special tools. However, these requirements do not result in a significant impact. A spare parts kit is available from the vendor. Consumables include items such as filters, gaskets, “O” rings, and bearings. The special tools required are delivered with the machine and consist of spanner wrenches made specifically for dismantling the purifier bowl.

4.2.1.6 Interface Requirements

Table 4-12 provides the interfaces required to support each WSC 50 centrifuge module.

Table 4-12. WSC 50 Interface Requirements (LHD 1 Class)

Shipboard System	WSC-50 (50-gpm per unit)
Electrical Power	440VAC/3PH, 80-130kW (107-174 hp)
Compressed Air	0.0045-0.022scfm 0.0058 - 0.029cfm @ 50 psig
Potable Water	50 gpd, 45 psi
Seawater	Requires 25 psi seawater pressure
Drainage	Gravity drain to OWHT

LHD 1 Class vessels are able to support these requirements with no significant impacts on existing systems.

4.2.1.7 Control System Requirements

Centrifuges are equipped with programmable logic controls and monitoring systems. The manufacturer recommends that the operator manually turn on the equipment. However, once the centrifuge has reached its operating speed, the WSC 50 does not require constant oversight. It is fully automatic and equipped with an integrated thermostat to control the heater.

A centrifuge may be equipped with an OCM to measure the oil content of OWS effluent. If the OCM detects an oil concentration greater than the predetermined desired concentration, the OCM will redirect the effluent back to the OWHT to be processed again by the OWS. The oil content monitor alarm can be monitored remotely or locally.

4.2.1.8 Other/Unique Characteristics

No other/unique characteristics have been identified with respect to this MPCD option.

4.2.2 Cost Analysis

The following cost data and calculations are provided to allow the reader to compare relative costs associated with a centrifuge system on the LHD 1 Class vessel.

4.2.2.1 Initial Cost

The centrifuge system (i.e., two units) procurement cost is $904,000 per vessel (Donohue, 2000). Based on a ship check of the LHD 4 (an LHD 1 Class vessel), the Navy estimates that installation of the two centrifuge units will cost $238,600 per vessel (Navy, 2000). The installation would require approximately eight weeks to complete. Technical manuals cost approximately $85,000 ($12,140 per vessel) to develop a 150-page manual (Gallagher, 1999). The Navy estimates that the development of technical drawings will cost $33,810 ($4,830 per vessel) (Navy, 2000). The cost for training materials is approximately $9,330 ($1,330 per vessel) (Smith, 2001). The total initial cost of a centrifuge system on an LHD 1 Class vessel is $1,161,000.

4.2.2.2 Recurring Cost

Personnel Labor Within 12 nm

This MPCD requires approximately 80 personnel hours per year for operation within 12 nm, condition-based maintenance, and time-based maintenance within 12 nm, as explained under Section 4.2.1.4. The number of annual labor hours multiplied by the $22.64 hourly MPCD operator labor rate produces the first operating year recurring labor cost within 12 nm.

$$\frac{\$22.64}{\text{hr}} \bullet \frac{80 \text{ hrs}}{\text{yr}} = \$1{,}800/\text{yr (inside 12 nm)}$$

Personnel Labor Beyond 12 nm

This MPCD requires 132 personnel hours per year for operation and condition-based maintenance, as explained under Section 4.2.1.4. The annual labor cost associated with operating this MPCD beyond 12 nm is calculated using the same hourly labor rate used to calculate the annual labor cost within 12 nm, as shown below.

$$\frac{\$22.64}{\text{hr}} \bullet \frac{132 \text{ hrs}}{\text{yr}} = \$2{,}980/\text{ yr (outside 12 nm)}$$

The labor required to transfer waste oil generated by the centrifuge system to a disposal activity is included in the above labor cost estimates. As explained in Section 1.1.2, the disposal activity is assumed to dispose of the waste oil at no charge for these vessels.

Table 4-13 summarizes the annual recurring costs for a centrifuge system on an LHD 1 Class vessel.

Table 4-13. Annual Recurring Costs for Centrifuge Systems (LHD 1 Class)

Vessel Operating Parameter	Disposal Cost Used	Annual Recurring Cost ($K)
Within 12 nm	Navy	1.8
Beyond 12 nm	Navy	2.98

4.2.2.3 Total Ownership Cost (TOC)

Table 4-14 summarizes the TOC and annualized cost over a 15-year lifecycle of a centrifuge system on an LHD 1 Class vessel.

Table 4-14. TOC for Centrifuge Systems (LHD 1 Class)

Cost ($K)	Vessel Operation Within 12 nm	Vessel Operation Within + Beyond 12 nm
Total Initial	1161	1161
Total Recurring	20	53
TOC (15-yr lifecycle)	1181	1214
Annualized	100	103

4.3 COLLECTION, HOLDING, TRANSFER (CHT)

The following sections discuss the feasibility and cost impacts of not discharging bilgewater (treated or untreated) from LHD 1 Class vessels to the environment within 12 nm from shore. This no-discharge option is referred to as the practice of CHT of bilgewater within 12 nm. The bilgewater may be transferred to shore facilities in port (including tanks, barges, and trucks) processed through an OWS beyond 12 nm, or discharged overboard, in accordance with applicable regulations beyond 12 nm.

For new design vessels, NSWCCD Code 20, Total Ship Systems Engineering Group, evaluated the feasibility and cost impacts of practicing CHT of surface vessel bilgewater.

4.3.1 Practicability and Operational Impact Analysis – Existing Vessels

This section analyzes specific feasibility criteria relative to the physical characteristics and operational requirements of practicing CHT.

4.3.1.1 Space and Weight

LHD 1 Class vessels are equipped with a series of OWHTs that have a combined design capacity of approximately 12,500 gallons. The OWHTs are designed with capacity 5-10 percent in excess of the ship's requirements to minimize the risk of overfilling the tanks, which would result in spillage. These tanks are designed to collect and hold oily waste (i.e., bilgewater) for processing by the vessel's 50-gpm OWS units or for transfer to shore, as applicable. As such, LHD 1 Class vessels are capable of practicing CHT up to the existing holding capacity without experiencing any impacts to space and weight. The potential for exceeding the vessel's existing space and weight capacities, as a result of practicing CHT, will depend upon the length of time spent within 12 nm from shore and whether the port visited has the capability to offload wastewater.

During a typical five-year operating cycle, LHD 1 Class vessels may visit many ports for varying lengths of time. The longest stays (i.e., 30 days or more) in port tend to be at the vessel's homeport or at other major Naval ports, where full shore services, including wastewater offloading, are available. During these visits, LHD 1 Class vessels usually do not run their OWS units, but instead transfer their bilgewater to shore facilities. However, to support their operational requirements, LHD 1 Class vessels may occasionally visit smaller non-Navy ports where offloading services are not available. In this situation, an LHD 1 Class vessel could be required to collect and hold all bilgewater generated until the ship is beyond 12 nm. The following paragraphs describe these two potential scenarios: (1) arriving at a port where offloading services are available, and (2) arriving at a port where offloading services are not available.

Ports with wastewater offloading services: All LHD 1 Class vessels are homeported in Norfolk, VA or San Diego, CA. These are major Naval ports with complete shore services, including wastewater offloading. Once a vessel has tied up pierside at one of these ports, bilgewater can be transferred as needed. LHD 1 Class vessels can also collect and hold bilgewater generated while transiting from 12 nm to port for transfer shoreside. For both of the homeports mentioned above, it takes approximately 2 to 3 hours to transit between port and 12 nm from shore. While underway, LHD 1 Class vessels generate approximately 25,000 gallons per day of bilgewater, or 1,041 gallons per hour. Using a generation rate of 1,041 gallons per hour over 3 hours, the maximum volume of bilgewater generated would be approximately 3,123 gallons. Once in port, LHD 1 Class vessels can transfer their bilgewater to shore as needed. Because the 3,123 gallons collected during transit is well within the holding capacity for LHD 1 Class vessels, practicing CHT while transiting to or from a port where shore offloading facilities are available will have no space or weight impacts.

Ports without wastewater offloading services: If LHD 1 Class vessels are visiting a port where offloading bilgewater is not possible, the ship could be required to hold all bilgewater during the entire time spent within 12 nm. A typical visit to a small port may last two to five days. Assuming a five-day port visit, an LHD would generate approximately 31,250 gallons of bilgewater (based on in port generation rate). Using a generation rate of 1,000 gallons per hour and a total transit time of 6 hours (3 hours in each direction), the assault ship would generate an additional 6,000 gallons of bilgewater while transiting to and from port. The total amount of bilgewater generated within 12 nm from shore would be approximately 37,250 gallons. This is three times the current safe holding capacity, and accommodating that volume would result in substantial adverse space and weight impacts. Under this scenario, an LHD 1 Class vessel would be limited to practicing CHT for a single day without exceeding its design holding capacity.

The practice of CHT within the existing holding capacity will not result in any space and weight impacts. While the above analyses describe typical operating scenarios, there may be situations where practicing CHT exceeds the vessel's existing holding capacity. Extra tank capacity would be required to accommodate any additional volume of bilgewater collected. Because most, if not all, space and weight allocations on LHD 1 Class vessels are tightly controlled, and because space is limited, there is generally very little unassigned space to which additional tankage can be added. Therefore, the most likely strategy for increasing bilgewater holding capacity would be to convert other existing tanks to bilgewater holding tanks. However, converting existing tank space to hold bilgewater would likely result in adverse impacts to those systems or services which rely on the tanks that would be converted for holding oily waste.

4.3.1.2 Personnel/Equipment Safety

Practicing CHT within the vessel's existing holding capacity will not pose any additional safety hazards to the vessel’s crew or equipment.

4.3.1.3 Mission Capabilities

Practicing CHT within the vessel's existing holding capacity will not have an impact on ship's signature, war-fighting capabilities, mobility, or on any mission critical systems or operations.

The ship designers review the ship's requirements (e.g., vessel's range, the number of crew, etc.) to determine what tank capacities are needed to allow the ship to fulfill its mission. With the exception of approximately five percent excess capacity as a margin of safety, ship designers do not size a vessel's tank capacity beyond what is necessary to meet the ship's requirements. Practicing CHT in excess of the vessel's existing holding capacity would likely require that additional tanks be built or tanks used for other purposes be converted to bilgewater holding tanks. Reducing the capacity of existing tanks such as aviation fuel (JP-5) tanks, potable water tanks, or sewage tanks, will reduce the ship's current capability to support its mission.

4.3.1.4 Personnel Impact

Practicing CHT within the vessel's existing holding capacity will not result in any personnel impacts other than time required to oversee the transfer of bilgewater and oily waste to shore (see analysis below).

Practicing CHT as a primary control option does not require special training. Manning is required to oversee the transfer of bilgewater to a shore facility (i.e., operate the oily waste transfer (OWT) pump and associated valves/hull connections). This transfer requires three workers per event as described in Section 4.1.1.4.

An LHD 1 Class vessel generates approximately 1,281,000 gallons of bilgewater annually within 12 nm. The annual volume of bilgewater generated within 12 nm of shore divided by the OWT pump rate (90 gpm) and multiplied by the number (three) of crewmembers required for oversight equals the personnel hours required per year for CHT on an LHD 1 Class vessel.

$$\frac{1{,}281{,}000\text{ gal}}{\text{yr}} \bullet \frac{\text{min}}{90\text{ gal}} \bullet \frac{\text{hr}}{60\text{ min}} \bullet \frac{3\text{ hrs labor}}{\text{hr}} = 710\text{ hrs labor/yr}$$

Table 4-15 provides the annual labor hours required for CHT.

Table 4-15. CHT Annual Labor Hours (LHD 1 Class)

	MPCD Option: CHT
Operator Hours Within 12 nm	710
Operator Hours Beyond of 12 nm	-
Condition-based Maintenance Within 12 nm	0
Condition-based Maintenance Beyond 12 nm	-
Time-based Maintenance	0
Total Time	710

4.3.1.5 Consumables, Repair Parts, and Tools

There are no requirements for consumables, repair parts, or tools associated with CHT.

4.3.1.6 Interface Requirements

Practicing CHT does not require any unique interface requirements. Oily waste transfer pumps and associated valves, piping, and hull connections exist on this vessel class to support the current practice of shoreside disposal.

4.3.1.7 Control System Requirements

There are no automated control system requirements associated with CHT. However, crewmembers are required by OPNAVINST 5090.1 (series) to watch for oily wastewater spills (e.g., during shoreside transfers) (Navy, 2002).

4.3.1.8 Other/Unique Characteristics

No other/unique characteristics have been identified with respect to this MPCD option group.

4.3.2 Cost Analysis – Existing Vessels

The following cost data and calculations are provided to allow the reader to compare relative costs associated with practicing CHT on an LHD 1 Class vessel. CHT is not practiced beyond 12 nm from shore; therefore, CHT costs are calculated for operation within 12 nm only. Vessels in this class will continue to comply with appropriate regulations beyond 12 nm.

4.3.2.1 Initial Cost

As described in Section 4.3.1.3, the reallocation of tank space to increase bilgewater holding capacity on an LHD 1 Class vessel would result in adverse impacts on mission capabilities and personnel. For the cost analysis, it was assumed that bilgewater holding capacity is adequate. Therefore, the initial cost of acquisition and installation of additional equipment such as tankage and piping systems is assumed to be zero.

4.3.2.2 Recurring Cost

LHD 1 Class vessels generate 1,281,000 gal of bilgewater within 12 nm annually and require 710 personnel hours per year for CHT manning, as explained under Section 4.3.1.4. The annual labor hours multiplied by the \$22.64 per hour MPCD operator labor rate produces the annual recurring labor cost of \$16,100.

$$\frac{\$22.64}{\text{hr labor}} \bullet \frac{710\text{ hrs labor}}{\text{yr}} = \$16{,}100/\text{yr}$$

The annual bilgewater generation rate within 12 nm is 1,281,000 gallons. The volume of bilgewater generated annually within 12 nm multiplied by the oily waste disposal unit cost produces the annual recurring disposal cost for CHT on an LHD 1 Class vessel of \$96,000.

$$\frac{1{,}281{,}000 \text{ gal}}{\text{yr}} \bullet \frac{\$0.0749}{\text{gal}} = \$96{,}000/\text{yr}$$

The total recurring cost of practicing CHT on an LHD 1 Class vessel is $112,100. There are no other Armed Forces vessels within the LHD 1 Class vessel grouping; therefore annual recurring costs were not calculated using other Armed Forces (i.e., Coast Guard) waste disposal figures.

Table 4-16 provides the annual recurring costs for practicing CHT on an LHD 1 Class vessel.

Table 4-16. Annual Recurring Costs for CHT (LHD 1 Class)

Vessel Operating Parameter	Disposal Cost Used	Annual Recurring Cost ($K)
Within 12 nm	Navy	112.1
Beyond 12 nm	Navy	-

4.3.2.3 Total Ownership Cost (TOC)

Table 4-17 provides the TOC and annualized cost over a 15-year lifecycle of practicing CHT on an LHD 1 Class vessel.

Table 4-17. TOC for CHT (LHD 1 Class)

Cost ($K)	Vessel Operation Within 12 nm	Vessel Operation Within + Beyond 12 nm
Total Initial	0.0	0.0
Total Recurring	1249	1249
TOC (15-yr lifecycle)	1249	1249
Annualized	106	106

4.3.3 Practicability and Operational Impact Analysis – New Design Vessels

This section analyzes specific feasibility criteria relative to the physical characteristics and operational requirements of practicing CHT on new design vessels.

4.3.3.1 Space and Weight

Ports with wastewater offloading services: As discussed in Section 4.3.1.1, practicing CHT while tied up pierside or transiting to or from a port where shore offloading facilities are available (assuming a total maximum transit time of six hours) will have no space or weight impacts.

Ports without wastewater offloading services: As discussed in Section 4.3.1.1, the current holding capacity of the OWHT (12,500 gallons) is not sufficient to hold all bilgewater generated during an extended port visit (typically two to five days) at a port where shore offloading facilities are not available. Based on typical operating scenarios and bilgewater generation rates, NSWCCD Code 20 determined that a tank (or series of tanks) with a capacity of approximately

41,000 gallons would be required to hold all bilgewater generated during an extended port visit. This is more than three times greater than the existing OWHT capacity and is a 1.0 percent increase in total dead weight. To support this additional tank volume, the size of the ship must be increased. Increasing the ship's size to support this additional dead weight will require approximately 140 long tons (LT) of additional structure, resulting in a total weight increase of approximately 250 LT and approximately 5 ft in overall ship length. This increase represents a 1.0 percent increase in full load weight over a current LHD 1 Class vessel. Furthermore, the additional structure required to accommodate a larger CHT system would increase the ship's volume by approximately 43,000 ft^3, of which only 3,800 ft^3 (approximately 8.75 percent) would be occupied by the CHT system (Navy, 2003b).

4.3.3.2 Personnel/Equipment Safety

Practicing CHT within the vessel's holding capacity on new design vessels will not pose any safety hazards to vessel equipment or crew.

4.3.3.3 Mission Capabilities

Practicing CHT within the vessel's designed holding capacity will not impact the mission-related operational capability of Navy vessels.

Operational scenarios do exist for LHD 1 Class vessels (amphibious-type vessel) that would require them to operate in shallow coastal waters for extended periods of time. LHD 1 Class vessels would be unable to practice CHT in excess of their holding capacity in these scenarios because of the potential impact to the ship's ability to meet critical mission-related activities (Navy, 2003b).

4.3.3.4 Personnel Impact

Practicing CHT would require approximately three crewmembers per event to conduct the transfer of oily wastes to shoreside facilities, as discussed under Section 4.1.1.4. Practicing CHT on new design vessels is expected to require approximately 710 total hours of labor per year (Navy, 2003b).

4.3.3.5 Consumables, Repair Parts, and Tools

There are no requirements for consumables, repair parts, or tools associated with practicing CHT on new design vessels.

4.3.3.6 Interface Requirements

Practicing CHT on new design vessels will not have an impact on interface requirements. No additional load would be placed on the ship's electrical plant (Navy, 2003b).

4.3.3.7 Control System Requirements

There are no automated control system requirements associated with CHT. However, crewmembers are required by OPNAVINST 5090.1 (series) to watch for oily wastewater spills (e.g., during shoreside transfers) (Navy, 2002).

4.3.3.8 Other/Unique Characteristics

No other/unique characteristics have been identified with respect to practicing CHT on new design vessels.

4.3.4 Cost Analysis – New Design Vessels

The following cost data and calculations are provided to allow the reader to compare relative costs associated with practicing CHT on a new design vessel in this vessel group. CHT is generally not practiced beyond 12 nm from shore; therefore, CHT costs are calculated for operation within 12 nm only. Vessels in this class must continue to comply with appropriate regulations when operating beyond 12 nm.

NSWCCD Code 20 estimated the total initial, total recurring, TOC, and annualized costs for practicing CHT on new design vessels in this vessel group. Table 4-18 summarizes those costs below. Code 20 concluded that the additional cost and increase in ship size required by a larger CHT system is not recommended for a system considered to be non-mission critical (Navy, 2003b).

4.3.4.1 Initial Cost

The required increase in OWHT volume (41,000 gallons vs. 12,500 gallons) would require new design vessels in this vessel group to add 140 LTs of additional steel, adding approximately $5.5 million to the initial acquisition cost of each ship (Navy, 2003b).

4.3.4.2 Recurring Cost

Practicing CHT requires 700 total labor hours per year for operation, as explained in Section 4.3.3.4. The labor and disposal costs associated with bilgewater disposal are estimated to be $112,000 annually for the Navy (Navy, 2003b).

4.3.4.3 Total Ownership Cost (TOC)

Table 4-18 summarizes the TOC of practicing CHT on an LHD 1 Class vessel below.

Table 4-18. TOC for CHT system On New Design Vessels (LHD 1 Class)

Cost ($K)	Vessel Operation Within 12 nm	Vessel Operation Within + Beyond 12 nm
Total Initial	5,500	5,500
Total Recurring	1,200	1,200
TOC (15-yr lifecycle)	6,700	6,700
Annualized	570	570

4.4 EVAPORATION

Commercial evaporation units are designed to operate with freshwater waste streams (Navy and EPA, 2000b). To apply evaporation technology in a saltwater environment, design concerns such as corrosivity, plating-out of salt in the unit, and buildup of sludge would need to be addressed before this technology could be considered feasible on this vessel class. The following analysis is provided to further describe the feasibility of this MPCD.

As stated in Section 4.0, LHD 1 Class vessels are equipped with two 50-gpm gravity coalescer OWSs with a combined processing rate of 100 gpm. Operating this MPCD in batch mode (i.e., operating at maximum capability to eliminate accumulating bilgewater) minimizes the impact on the vessel's crew A bilgewater evaporator with the maximum available processing rate, one gallon per minute, was chosen for this analysis to minimize the number of units required. A total of 100 evaporation units, each requiring 162 kW of electrical power to operate, would be required to meet the current processing rate. LHD 1 Class vessels have a total electrical capacity of 12,500 kW and a designed operating capacity of 9,000 kW. The designed operating capacity is based on the assumption that one ship service generator is out of service and the remaining generators are operating at 90 percent capacity (Navy, 1980). The designed operating capacity includes a 20 percent service life margin (1,500 kW) to support the addition of electrical equipment throughout the vessel's lifecycle (Navy, 1980). The service life margin represents the total electrical capacity available to support additional electrical equipment that may be installed following initial construction. The use of evaporators would constitute a total electrical load of 16,200 kW, which is greater than the 1,500 kW service life margin available.

A significant amount of electrical power is required by Armed Forces vessels to support mission-related payloads, such as the combat systems (e.g., weapons, command, communications, control, electronic warfare and countermeasures, etc.) and combat support and supply systems. Because the use of evaporators would exceed the vessel's service life margin, mission essential electrical equipment would have to be shut off while running the evaporators. This equipment is essential for vessel safety and defense. Not operating this equipment while running the evaporators would leave the vessel vulnerable to safety hazards (e.g., collisions) and potential military threats. Furthermore, despite the flexibility afforded by new design vessels (e.g., reduced cost of forward-fit installation), new design vessels are not expected to be able to support the evaporators' substantial power requirements. Therefore, based on the evaporators' power requirements that subsequently degrade the vessel's mission and safety capabilities, evaporation is not a feasible MPCD option group for either existing or new design vessels represented by the LHD 1 Class. In addition, design concerns such as corrosivity, plating out of salt in the unit, and buildup of salt and sludge still need to be addressed before this technology may be feasible on this vessel class.

4.5 HYDROCYCLONES

The following sections discuss the feasibility and cost impacts of installing and operating hydrocyclones on-board LHD 1 Class vessels.

4.5.1 Practicability and Operational Impact Analysis

This section analyzes specific feasibility criteria relative to the physical characteristics and operational requirements of a hydrocyclone unit.

4.5.1.1 Space and Weight

A single 100-gpm hydrocyclone system (Krebs CycloClean System) is being proposed in this analysis. This model was chosen because it has equivalent processing capacity as the current MPCDs installed on LHD 1 Class vessels. A single 100-gpm unit was chosen rather than two 50-gpm units. Because the 50-gpm unit and the 100-gpm unit are identical, with the exception of the feed pump rate, using two 50-gpm hydrocyclone units versus a single 100-gpm unit would unnecessarily double the space and weight impacts of the MPCD. The hydrocyclone units are custom engineered and can be made to accommodate the desired flow rate. The hydrocyclone assembly is normally oriented horizontally, but could be oriented vertically if necessitated by space requirements. Table 4-19 provides the space and weight for a 100-gpm skid mounted model consisting of a strainer basket, helical rotor pump, 12 inch diameter vessel, and interconnecting piping.

Table 4-19. Hydrocyclone Specifications (LHD 1 Class)

Physical Properties	Number of Units	Capacity	Size (ft.) L x W x H	Maintenance Envelope (ft.)	Volume (ft^3)	Weight (lbs.) Dry/Flooded
Per unit	1	100 gpm	7 x 6 x 4	10 x 8 x 6	168	900/1000
Total (To achieve required processing capacity)	1	100 gpm	-	-	168	900/1000

Hydrocyclone units are designed for single-deck operation and would be installed in the current OWS room. The two existing OWSs would be removed and replaced with a single hydrocyclone unit in the same location.

4.5.1.2 Personnel/Equipment Safety

There are no unusual personnel or equipment safety hazards associated with hydrocyclones. Other than wearing standard personal protective equipment (e.g., rubber gloves/boots and safety glasses/goggles) during maintenance activities, no special devices or precautions are necessary. Any hazardous materials (e.g., oil and grease) required for operation and maintenance are minimal in quantity and authorized for use. Standard afloat control and management procedures are adequate for use and disposal of the material. While hydrocyclones require electrical power, standard shipboard safety procedures for handling electrical equipment should be adequate.

4.5.1.3 Mission Capabilities

The installation and operation of hydrocyclones on LHD 1 Class vessels is not expected to have an impact on ship's signature, war fighting capabilities, mobility, or on any mission critical systems or operations.

4.5.1.4 Personnel Impact

The hydrocyclone system runs in automatic mode, but still requires general supervision while the unit is operating. Based on an MPCD rated capacity of 100 gpm and approximately 1,281,000 gallons of bilgewater generated annually within 12 nm, the number of hours the hydrocyclone is operated annually within 12 nm is 214 hours.

$$\frac{1{,}281{,}000\text{ gal}}{\text{yr}} \bullet \frac{\text{min}}{100\text{ gal}} \bullet \frac{\text{hr}}{60\text{ min}} = 214\text{ hrs/yr}$$

The labor requirement for general oversight of the hydrocyclone was calculated as 0.25 hours (15 minutes) for every two hours of operation. The supervisory labor requirement of 15 minutes for every two hours of operation is based on the assumption that although the unit is automatic, a crewmember will be assigned to general oversight of multiple pieces of equipment at once. Therefore, based on the annual operating requirement of 214 hours, the annual labor requirement associated with the operation of the hydrocyclone within 12 nm is 27 hours, as calculated below:

$$\frac{214\text{ hrs operation}}{\text{yr}} \bullet \frac{0.25\text{ hr labor}}{2\text{ hrs operation}} = 27\text{ hrs labor/yr}$$

In addition, the waste oil removed from the bilgewater must be transferred to a shore facility. This transfer requires three crewmembers per event as described Section 4.1.1.4. The labor hours associated with transferring the waste oil produced within 12 nm from shore by the hydrocyclone on LHD 1 Class are calculated by dividing the waste oil volume (1 percent of the annual volume of bilgewater generated within 12 nm) by the waste oil pump rate (54 gpm) and multiplying by the number (three) of crewmembers.

$$\frac{12{,}810\text{ gal}}{\text{yr}} \bullet \frac{\text{min}}{54\text{ gal}} \bullet \frac{\text{hr}}{60\text{ min}} \bullet \frac{3\text{ hrs labor}}{\text{hr}} = 12\text{ hrs labor/yr}$$

The combined annual labor associated with the operational oversight of the hydrocyclone within 12 nm and transfer of waste oil generated within 12 nm on an LHD 1 Class vessel is 39 hours.

The total labor requirement associated with vessel operation beyond 12 nm includes MPCD operator oversight (i.e., 15 minutes for every two hours of equipment operation) and labor required to oversee the offloading of waste oil to shore attributable to vessel operation beyond 12 nm. The approximate volume (i.e. 4,375,000 gal) of bilgewater generated beyond 12 nm and resultant volume (i.e. 43,750 gal) of waste oil that requires offloading to shore are based on the LHD 1 Class vessel underway bilgewater generation rate of 25,000 gpd. The underway generation rate is multiplied by the number of days (175 days) spent beyond 12 nm. Hours of MPCD operation and annual labor requirements are presented below.

Hours of MPCD operation beyond 12 nm:

$$\frac{4{,}375{,}000 \text{ gal}}{\text{yr}} \bullet \frac{\text{min}}{100 \text{ gal}} \bullet \frac{\text{hr}}{60 \text{ min}} = 729 \text{ hrs/yr}$$

Labor requirement for MPCD operator oversight:

$$\frac{729 \text{ hrs}}{\text{yr}} \bullet \frac{0.25 \text{ hrs labor}}{2 \text{ hrs}} = 91 \text{ hrs labor/yr}$$

Labor requirement for offloading waste oil:

$$\frac{43{,}750 \text{ gal}}{\text{yr}} \bullet \frac{\text{min}}{54 \text{ gal}} \bullet \frac{\text{hr}}{60 \text{ min}} \bullet \frac{3 \text{ hrs labor}}{\text{hr}} = 41 \text{ labor hrs/yr}$$

Total MPCD operator labor and waste oil offloading oversight associated with the operation of the hydrocyclone system on LHD 1 Class vessels beyond 12 nm is 132 hrs/yr.

Annually, the hydrocyclone requires approximately 7.1 personnel hours of time-based maintenance, 0 personnel hours of condition-based maintenance within 12 nm, and 0 personnel hours of condition-based maintenance beyond 12 nm. Table 4-20 and Table 4-21 summarize the time-based maintenance and the condition-based maintenance requirements, respectively, for a hydrocyclone unit.

Table 4-20. Hydrocyclone Time-Based Maintenance (LHD 1 Class)

Maintenance Activity	Maintenance Time (hours)	Frequency	Annualized Maintenance Time (hours)
Clean and Inspect Strainer Basket	0.25	1 to 3 months	.75
Open and Inspect Hydrocyclone Bundle	2	12 months	2
Inspect Positive Displacement Pump for Wear	1	18 months	0.75
Rebuild Positive Displacement Pump Rotors	10	18 to 36 months	3.6
Total Annual Labor per unit	-	-	7.1
Total Annual Labor per vessel	-	-	7.1

Table 4-21. Hydrocyclone Condition-Based Maintenance (LHD 1 Class)

Maintenance Activity	Maintenance Time (hours)	Frequency (based on hours of MPCD operation)	Annualized Maintenance Hours (based on operation hours within 12 nm)	Annualized Maintenance Hours (based on operation hours beyond 12 nm)
None	0	0	0	0
Total Annualized Hours	-	-	0	0

Table 4-22 provides the annual labor hours required to operate and maintain a hydrocyclone module.

Table 4-22. Hydrocyclone Annual Labor Hours (LHD 1 Class)

	MPCD Option: Hydrocyclone
Operator Hours Within 12 nm	39
Operator Hours Beyond of 12 nm	132
Condition-based Maintenance Within 12 nm	0
Condition-based Maintenance Beyond 12 nm	0
Time-based Maintenance	7.1
Total Time	178

Hydrocyclones do not have an impact on habitability. Hydrocyclones are closed systems, so no vapors are present. Manning requirements will be minimal because the hydrocyclones require very little maintenance, and operation can be fully automated. Periodic monitoring of the inlet and underflow pressures would be recommended to evaluate operating conditions and determine if maintenance is needed.

4.5.1.5 Consumables, Repair Parts, and Tools

Consumables and repair parts, which should be on hand, include “O” rings and gaskets for the cyclone vessel, a few spare cyclone liners, and some components (e.g., spare diaphragm) for the pump. Consumables and repair parts do not represent a major impact.

4.5.1.6 Interface Requirements

Table 4-23 summarizes specific system interface requirements associated with the hydrocyclones.

Table 4-23. Hydrocyclone Interface Requirements (LHD 1 Class)

Shipboard System	100-gpm unit
Electrical Power	3.7 kW (5 hp), 460VAC, 3 Phase, 60 Hz

The LHD 1 Class vessels are able to accommodate this interface requirement with no significant impacts on existing systems.

4.5.1.7 Control System Requirements

The hydrocyclones are designed to operate in either automatic or manual mode. Automatic operation is the normal operating mode. When placed in the automatic mode, activation of the unit is controlled by tank level switches installed in the OWHT. When the volume of the liquid reaches a pre-set level, one level switch will start the unit. When the liquid level in the OWHT drops to a pre-set level, a second level switch signals the unit to shut down. The unit has a flow sensor that will secure the system if the pump loses suction and a remote alarm/indicator panel. This feature allows shipboard personnel to monitor the operating status of the unit while in the automatic mode of operation.

A hydrocyclone may be equipped with an oil content monitor (OCM) to measure the oil content of OWS effluent. If the OCM detects an oil concentration greater than the predetermined desired concentration, the OCM will redirect the effluent back to the OWHT to be processed again by the OWS.

4.5.1.8 Other/Unique Characteristics

No other/unique characteristics have been identified with respect to this MPCD option.

4.5.2 Cost Analysis

The following cost data and calculations are provided to allow the reader to compare relative costs associated with a hydrocyclone system on the LHD 1 Class vessel.

4.5.2.1 Initial Cost

The hydrocyclone system (i.e., one unit) procurement cost is $62,000 (Benjamin, 2000). Installation cost includes the cost of labor, materials, and oversight to install the unit. Based on a ship check of the LHD 4 (an LHD 1 Class vessel), the Navy estimates that installation of the 100-gpm hydrocyclone unit will cost $124,000 (Navy, 2000). To install the hydrocyclone, the two existing gravity coalescence units must first be removed in order to make space available for the hydrocyclone system. The installation would require approximately six weeks to complete. Technical manuals cost approximately $85,000 ($12,140 per vessel) to develop a 150-page manual (Gallagher, 1999). The Navy estimates that the development of technical drawings will cost $25,120 ($3,588 per vessel) (Navy, 2000). The cost for training materials is approximately $9,330 ($1,330 per vessel) (Smith, 2001). The initial cost of a hydrocyclone system on an LHD 1 Class vessel is $203,000.

4.5.2.2 Recurring Cost

Personnel Labor Within 12 nm

This MPCD requires 46 personnel hours per year for operation, condition-based maintenance, and time-based maintenance within 12 nm as explained under Section 4.5.1.4. The number of annual labor hours multiplied by the $22.64 hourly MPCD operator labor rate produces the first operating year recurring labor cost within 12 nm.

$$\frac{\$22.64}{\text{hr labor}} \bullet \frac{46 \text{ hrs labor}}{\text{yr}} = \$1{,}000/\text{yr (inside 12 nm)}$$

Personnel Labor Beyond 12 nm

This MPCD requires 132 personnel hours per year for operation and condition based maintenance beyond 12 nm, as explained under Section 4.5.1.4. The annual labor cost associated with operating this MPCD beyond 12 nm is calculated using the same hourly labor rate used to calculate the annual labor cost within 12 nm, as shown below.

$$\frac{\$22.64}{\text{hr labor}} \bullet \frac{132 \text{ hrs labor}}{\text{yr}} = \$2{,}980/\text{yr}$$

The labor required to transfer waste oil generated by the hydrocyclone system to a disposal activity is included in the above labor cost estimates. As explained in Section 1.1.2, the disposal activity is assumed to dispose the waste oil at no charge for these vessels. There are no Coast Guard vessels within the LHD 1 vessel grouping; therefore, annual recurring costs were not calculated using Coast Guard waste disposal figures.

Table 4-24 provides annual recurring costs for a hydrocyclone system on an LHD 1 Class vessel.

Table 4-24. Annual Recurring Costs for Hydrocyclone (LHD 1 Class)

Vessel Operating Parameter	Disposal Cost Used	Annual Recurring Cost ($K)
Within 12 nm	Navy	1.0
Beyond 12 nm	Navy	2.98

4.5.2.3 Total Ownership Cost (TOC)

Table 4-25 summarizes the TOC and annualized cost over a 15-year lifecycle of a hydrocyclone system on an LHD 1 Class vessel.

Table 4-25. TOC for Hydrocyclone (LHD 1 Class)

Cost ($K)	Vessel Operation Within 12 nm	Vessel Operation Within + Beyond 12 nm
Total Initial	203	203
Total Recurring	11	44
TOC (15-yr lifecycle)	214	247
Annualized	18	21

4.6 *IN SITU* BIOLOGICAL TREATMENT

In Situ biological treatment of bilgewater is the addition of microbes to a vessel's bilge spaces to metabolize the oil content of the bilgewater. For in situ biological treatment to be effective, the microbes must be left in the bilge for a sufficient period of time to digest the bilgewater's oil content. According to the vendor, the most effective use of in situ biological treatment for the wastewater that accumulates in the bilge is to leave the in situ material in the bilge spaces on the vessel for a 30-day period to establish a population of microbes (Opsanick, 2000). Transferring bilgewater to shore or allowing additional bilgewater to be introduced to the bilge spaces before the 30-day period is complete may decrease the in situ biological treatment's effectiveness. Due to the lack of performance data, the extent to which the effectiveness of biological treatment would be decreased cannot be determined (Opsanick, 2000). However, the vessel would be continuously generating bilgewater during this period, disrupting the batch processing method recommended by the manufacturer. Further, the vessel's total bilgewater generation over a 30-day period is at least 187,000 gallons. Leaving this volume of bilgewater in the bilge spaces to allow more complete treatment would inhibit the safe operation of existing or new design vessels. Therefore, *in situ* biological treatment is not a feasible MPCD option group for existing or new design vessels represented by LHD 1 Class vessels.

4.7 OIL ABSORBING SOCKS (OASS)

OASs are designed to absorb oil floating on the surface of a body of water (Sorbent Products Inc., 2000). In this application, OASs would be placed inside the bilge areas of an LHD 1 Class vessel to continuously absorb the waste oil from the bilgewater. When the OASs become fully saturated, they are manually removed, stored, and replaced with new OASs. This use of OASs for LHD 1 Class vessels poses a concern regarding the generation of solid waste, potential to restrict emergency dewatering, and a potential fuel source that could contribute to the intensity of an engine room fire.

The use of OASs for LHD 1 Class vessels will result in the generation of a large amount of solid waste. As noted earlier, LHD 1 Class vessels generate approximately 62.5 gallons of waste oil per day while in port and 250 gallons per day while underway. The density of a saturated OAS is approximately 7.3 pounds per gallon of waste oil (Ergon Environmental Products Inc., 1998). OASs are solid media that trap and hold waste oil, a liquid. Therefore, using OASs would generate approximately 460 pounds of solid waste per day while in port. If used underway, OASs would generate approximately 1,800 pounds of solid waste per day. The removal of saturated OASs would require a high level of manual effort (i.e., labor provided by the ship's crew). The saturated OASs would need to be removed from the bilge and carried up from the lower decks of the vessel so they could be transferred to shore. By comparison, waste oil captured by the current MPCD option (i.e., the gravity coalescing OWS) remains a liquid waste stream and would only require a few minutes to pump the same amount ashore.

The presence of OASs in the bilge spaces would potentially restrict the flow of bilgewater through normal and emergency dewatering pumps and strainers by clogging the suction points. The use of OASs in the bilge spaces of Navy vessels would not be feasible due to vessel safety and survivability concerns. The Navy prohibits (through practice) the presence of any loose materials or debris in the bilge areas that could potentially interfere with normal or emergency dewatering activities. Securing the OASs to a pipe or other type of fixture in the bilge is not feasible because the force of a shock or explosion would potentially dislodge the OAS. Furthermore, as the OAS absorbs oil, it becomes a concentrated fuel source that could contribute to the intensity of an engine room fire.

Based on the potential operational and safety impacts related to solid waste handling, emergency dewatering, and potential fire hazards, OASs are not a feasible MPCD option group for the LHD 1 Class vessel group. New design vessels cannot resolve these impacts.

4.8 FILTER MEDIA

The following sections discuss the feasibility and cost impacts of installing and operating a filter media unit on an LHD 1 Class vessel. The polishing unit consists of oil absorbing filter media canisters and is designed to treat OWS effluent before being discharged overboard. Although primary OWSs installed on-board LHD 1 Class vessels generally have a combined rated capacity of approximately 100 gpm, due to space constraints, the filter media polishing unit is only being proposed in conjunction with one of the 50-gpm OWSs. The 50-gpm filter media unit was selected as a secondary MPCD on the basis of size and its ability to match the capacity requirements of the current MPCD. The Navy expects this capacity to be sufficient for processing the amount of bilgewater generated within 12 nm where an effluent with low oil concentration is most critical. Once beyond 12 nm, the vessel could operate its primary OWS and continue to operate in compliance with regulatory requirements.

4.8.1 Practicability and Operational Impact Analysis

Filter media polishing units consist of oil absorbing filter media and are designed to treat OWS effluent before it is discharged overboard. This section analyzes specific feasibility criteria relative to the physical characteristics and operational requirements of filter media secondary OWS systems.

4.8.1.1 Space and Weight

In order to process 50 gpm of OWS effluent on an LHD 1 Class vessel, five 10-gpm polisher units can be connected in parallel. Each filter media polisher contains nine media canisters (45 canisters total). The cylindrical canisters can be stacked and have a height of 13 inches and a diameter of 12 inches. On the representative vessel, an existing workbench and storage locker would have to be removed, and the deballasting expansion tanks and some minor piping would need to be relocated to make space for the five 10-gpm filter media polisher units in the existing OWS room (Navy, 2000). It is anticipated that alterations on a similar scale would be required on the other vessels in this group. Table 4-26 summarizes the approximate space and weight of these 10-gpm units.

Table 4-26. OWS Filter Media Polisher Specifications (LHD 1 Class)

Physical Properties	Number of Units	Capacity	Size (ft.) L x W x H	Maintenance Envelope (ft.)	Volume (ft^3)	Weight (lbs.) Dry/Flooded
Per unit	1	10 gpm	4 x 1.3 x 3.25	5.6 x 2.8 x 5.25	16.9	730/1675
Total (To achieve required processing capacity)	5	50 gpm	-	-	84.5	3650/8375

4.8.1.2 Personnel/Equipment Safety

There are no unusual personnel or equipment safety hazards associated with this MPCD. Other than wearing standard personal protective equipment (e.g., rubber gloves/boots and safety glasses/goggles) during maintenance activities, no special devices or precautions are necessary. Any hazardous materials (e.g., oil and grease) required for operation and maintenance are minimal in quantity and authorized for use. Standard afloat control and management procedures are adequate for use and disposal of the material.

4.8.1.3 Mission Capabilities

The installation and operation of this MPCD on LHD 1 Class vessels is not expected to have an impact on ship's signature, war fighting capabilities, mobility, or on any mission critical systems or operations.

4.8.1.4 Personnel Impact

OWS filter media polisher systems run in automatic mode, but require general supervision while the unit is operating. The number of hours the polisher system is operated annually within 12 nm is 420 hours.

$$\frac{1{,}268{,}000 \text{ gal}}{\text{yr}} \bullet \frac{\text{min}}{50 \text{ gal}} \bullet \frac{\text{hr}}{60 \text{ min}} = 420 \text{ hrs/yr}$$

It is assumed that because a secondary OWS unit runs in conjunction with a primary OWS unit, the secondary units will not require significant additional oversight. Therefore, operator oversight hours associated with secondary units are assumed to be zero.

The recovered waste oil is absorbed into filter media canisters and must be offloaded. The time required to replace the filter media canisters is one hour for each unit, for a total of five hours for all five units. The filter media canisters must be replaced after approximately 400 hours of operation (Galecki, 2000). With a total rated capacity of 50 gpm and a total of 1,268,000 gallons of effluent to be processed annually (equal to bilgewater generated annually within 12 nm minus one percent of oil removed by primary OWS), the filter media will have to operate approximately 420 hours per year to process the bilgewater generated within 12 nm. Therefore, the filter media will have to be replaced every 11.3 months. The annual number of hours spent replacing the filter media canisters is 5.3 hours per year.

$$\frac{1{,}268{,}000\text{ gal}}{\text{yr}} \bullet \frac{\text{min}}{50\text{ gal}} \bullet \frac{\text{hr}}{60\text{ min}} \bullet \frac{5\text{ hrs labor}}{400\text{ hr}} = 5.3\text{hrs labor/yr}$$

The storage of spare canisters and the offloading of expended canisters will not impose a significant impact on the vessel's crew and will not be considered here or in the cost section.

Annually, the filter media canisters require approximately 0 personnel hours of time-based maintenance, 5.3 personnel hours of condition-based maintenance within 12 nm, and 0 personnel hours of condition-based maintenance beyond 12 nm. Table 4-27 and Table 4-28 summarize the time-based maintenance and the condition-based maintenance requirements, respectively, for a filter media unit. Table 4-29 provides the annual labor hours required to operate and maintain the proposed MPCD discussed in this section.

Table 4-27. Filter Media Time-Based Maintenance (LHD 1 Class)

Maintenance Activity	Maintenance Time (hours)	Frequency	Annualized Maintenance Time (hours)
None	0	0	0
Total Annual Labor per unit	-	-	0
Total Annual Labor per vessel	-	-	0

Table 4-28. Filter Media Condition-Based Maintenance (LHD 1 Class)

Maintenance Activity	Maintenance Time (hours)	Frequency (based on hours of MPCD operation)	Annualized Maintenance Hours (based on450 operation hours within 12 nm)	Annualized Maintenance Hours (based on 2437 operation hours beyond 12 nm)
Replace Filter Media Canisters	5	400	5.3	0
Total Annualized Hours	-	-	5.3	0

Table 4-29. Filter Media Annual Labor Hours (LHD 1 Class)

	Filter Media
Operator Hours Within 12 nm	0
Operator Hours Beyond of 12 nm	0
Condition-based Maintenance Within 12 nm	5.3
Condition-based Maintenance Beyond 12 nm	0
Time-based Maintenance	0
Total Time	5.3

4.8.1.5 Consumables, Repair Parts, and Tools

The OWS filter media polishing unit requires the replacement of 45 filter media canisters (9 canisters per unit times 5 units). The canisters may be stored on the vessel or shoreside. Filter media canisters are considered spent if the pressure drop across the polisher unit exceeds 12 psi. No special repair parts or tools are required for the operation or maintenance of these units.

4.8.1.6 Interface Requirements

No specific system interface requirements are associated with the OWS filter media polishing system.

4.8.1.7 Control System Requirements

The OWS filter media polishing system operates automatically in response to the primary OWS operation. Therefore, the polisher unit does not have any unique control system requirements.

4.8.1.8 Other/Unique Characteristics

No other/unique characteristics have been identified with respect to this MPCD option group.

4.8.2 Cost Analysis

The following cost data and calculations are provided to allow the reader to compare relative costs associated with using and installing the filter media MPCD on an LHD 1 Class vessel.

4.8.2.1 Initial Cost

The filter media system procurement cost is $15,680 per unit, or $78,380 per system (i.e., five units) (Hanrahan, 1997). Based on a ship check of LHD 4 (an LHD 1 Class vessel), the Navy estimates that installation of the filter media system on an LHD 1 Class vessel would cost $150,400 per vessel (Navy, 2000). The unit would be installed in the OWS room, where removal of the existing workbench and HAZMAT locker and minor piping and equipment relocations would be required to make space available. The installation would require approximately five weeks to complete. Technical manuals cost approximately $85,000 ($12,140 per vessel) to develop a 150-page manual (Gallagher, 1999). The development of technical drawings will cost $20,290 ($2,899 per vessel) (Navy, 2000). The cost for training materials is approximately $9,330 ($1,333 per vessel) (Smith, 2001). The total initial cost of a filter media system on an LHD 1 Class vessel is $245,000 per vessel.

4.8.2.2 Recurring Cost

This MPCD requires 5.3 personnel hours per year for condition-based maintenance within 12 nm, as explained under Section 4.8.1.4. The number of annual labor hours multiplied by the $22.64 hourly MPCD operator labor rate produces the annual labor cost within 12 nm.

$$\frac{\$22.64}{\text{hr labor}} \bullet \frac{5.3 \text{ hrs labor}}{\text{yr}} = \$120/\text{yr (within 12 nm)}$$

The replacement cost of filter media canisters is $7000/unit. Because this vessel class requires five units, the cost for canister consumables at each replacement interval is $35,000. The filter media canisters must be replaced after approximately 400 hours of operation (Galecki, 2000). With a total rated capacity of 50 gpm and a total of 1,268,000 gallons of effluent to be processed annually, the filter media will have to operate approximately 420 hours per year. Therefore, the filter media will have to be replaced every 11.3 months, which results in an annual cost of $37,000.

$$\frac{1{,}268{,}000\text{ gal}}{\text{yr}} \bullet \frac{\text{min}}{50\text{ gal}} \bullet \frac{\text{hr}}{60\text{ min}} \bullet \frac{1\text{ replacement}}{400\text{ hrs}} \bullet \frac{\$35{,}000}{\text{replacment}} = \$37{,}000/\text{yr}$$

The filter media canisters are combined and disposed of with the vessels' solid waste. Because of the relative infrequency and small volumes disposed, the Navy does not expect any significant increase in their overall solid waste disposal cost.

The filter media canisters absorb the oil content of the oily bilgewater. Because media canisters absorb the oil content, the filter media system does not produce waste oil that must be offloaded from the vessel. The annual recurring costs for a filter media system used on an LHD 1 Class vessel are summarized in Table 4-30. There are no Coast Guard vessels within the LHD 1 vessel grouping; therefore, annual recurring costs were not calculated using Coast Guard waste disposal figures.

Table 4-30. Annual Recurring Costs for Filter Media (LHD 1 Class)

Vessel Operating Parameter	Disposal Cost Used	Annual Recurring Cost ($K)
Within 12 nm	-	37
Beyond 12 nm	-	-

4.8.2.3 Total Ownership Cost (TOC)

Table 4-31 summarizes the TOC and annualized cost over a 15-year lifecycle for a filter media system on an LHD 1 Class vessel.

Table 4-31. TOC for Filter Media (LHD 1 Class)

Cost ($K)	Vessel Operation Within 12 nm	Vessel Operation Within + Beyond 12 nm
Total Initial	245	245
Total Recurring	412	412
TOC (15-yr lifecycle)	660	660
Annualized	56	56

4.8.3 Applicability of the Filter Media Analysis to New Design Vessels

The practicability and operational impact of using filter media systems on new design vessels in this vessel group are expected to be similar to the impact on existing vessels in this group, as represented by LHD 1 Class vessels. The installation cost would be different for new design vessels, however all other costs are not expected to change. Therefore, except for the installation cost and the adjusted TOC, this new design analysis refers to Sections 4.8.1 and 4.8.2 for all other feasibility factors. As discussed in Section 1.2, to estimate the new design installation cost, a factor of 67 percent was applied to the filter media installation cost estimate for existing vessels within this group. Using this factor, the assumed installation costs for the new design LHD 1 vessel group is $100,800, per vessel. The total projected initial cost for a filter media system aboard these new design vessels is $196,000, per vessel. Table 4-32 summarizes the costs for these new design vessels.

Table 4-32. TOC for Filter Media on New Design Vessels (LHD 1 Class)

Cost ($K)	Vessel Operation Within 12 nm	Vessel Operation Within + Beyond 12 nm
Total Initial	196	196
Total Recurring	412	412
TOC (15-yr lifecycle)	608	608
Annualized	52	52

4.9 MEMBRANE FILTRATION

The following sections discuss the feasibility and cost impacts of installing and operating a membrane filtration [ultrafiltration (UF)] secondary treatment OWS unit on-board LHD 1 Class vessels. This UF unit is designed to treat OWS effluent before being discharged overboard.

4.9.1 Practicability and Operational Impact Analysis

This section analyzes specific feasibility criteria relative to the physical characteristics and operational requirements of membrane filtration.

4.9.1.1 Space and Weight

A 50-gpm UF unit was selected as the secondary MPCD. Although primary OWSs installed on-board LHD 1 Class vessels generally have a combined rated capacity of 100 gpm, due to space constraints, the UF unit is only being proposed in conjunction with one of the 50-gpm OWSs. The Navy expects one unit to be sufficient for processing the amount of bilgewater generated within 12 nm where an effluent with lower oil concentration is most critical. Once beyond 12 nm, the vessel will operate its primary OWS and continue to operate in compliance with regulatory requirements. Table 4-33 provides the space and weight of a 50-gpm unit.

Table 4-33. Membrane Filtration Unit Specifications (LHD 1 Class)

Physical Properties	Number of Units	Capacity	Size (ft.) L x W x H	Maintenance Envelope (ft.)	Volume (ft^3)	Weight (lbs.) Dry/Flooded
Per unit	1	50 gpm	24.5 x 3 x 6	26.5 x 5 x 8	441	9,200/12,000
Total (To achieve required processing capacity)	1	50 gpm	24.5 x 3 x 6	26.5 x 5 x 8	441	9,200/12,000

According to a ship check of the LHD 5 (an LHD 1 Class vessel) conducted by the Navy's Alteration Installation Team (AIT), the UF unit could be installed in the No. 2 auxiliary machinery room where the current OWSs are located. However, because the machinery spaces on the first three LHD 1 Class vessels (LHD 1, 2, and 3) were allocated differently, these specific vessels do not have the open space available on the later LHD 1 Class vessels. Installing the UF unit on the three oldest vessels in this class would require extensive modifications to the deballasting and fire suppression systems and a reconfiguration of the UF unit's layout.

UF membrane units are designed for single-deck operation. They can be provided to the installing activity fully assembled, or designed for easy disassembly into components small enough to fit through standard watertight doors.

Installing a 50-gpm membrane system on LHD 1 Class vessels would have space and weight impacts. Due to variations in the machinery space configurations, the extent of these impacts will vary within the vessel class.

4.9.1.2 Personnel/Equipment Safety

There are no unusual personnel or equipment safety hazards associated with membrane systems. Other than wearing standard personal protective equipment (e.g., rubber gloves/boots and safety glasses/goggles) during maintenance activities, no special devices or precautions are necessary. Any hazardous materials (e.g., oil and grease) required for operation and maintenance are minimal in quantity and authorized for use. Standard afloat control and management procedures are adequate for use and disposal of the material. While membrane systems require electrical power and operate under high pressure, observing standard shipboard safety procedures for handling electrical equipment and pressurized systems should be adequate. A Failure Mode, Effects and Criticality Analysis (FMECA) was generated for the UF system used on the USS CARNEY (DDG 51 Class vessel). The FMECA lists potential system failures according to their relative probability of occurrence, identifies safety hazards resulting from those failures, and recommends safety practices to reduce the associated safety risk. Applicable safety practices recommended by the FMECA will likely be implemented in conjunction with UF system installation on-board the LHD 1 Class vessels.

4.9.1.3 Mission Capabilities

The installation and operation of a UF membrane on LHD 1 Class vessels is not expected to have an impact on ship's signature, war fighting capabilities, mobility, or on any mission critical systems or operations.

4.9.1.4 Personnel Impact

UF systems run in automatic mode, but require some basic oversight while the unit is operating. The number of hours the UF system is operated annually within 12 nm is 420 hours.

$$\frac{1{,}268{,}000 \text{ gal}}{\text{yr}} \bullet \frac{\text{min}}{50 \text{ gal}} \bullet \frac{\text{hr}}{60 \text{ min}} = 420 \text{ hrs/yr}$$

It is assumed that because a secondary OWS unit runs in conjunction with a primary OWS unit, the secondary units will not require significant additional oversight. Therefore, operator oversight hours associated with secondary units are assumed to be zero.

The waste oil removed from the bilgewater by the UF system must be transferred to a shore facility. This transfer requires three crewmembers per event as described under the Section 4.1.1.4. The labor hours associated with oversight of transfer of waste oil produced by a UF system on LHD 1 Class vessels are calculated by dividing the waste oil volume to be offloaded (1 percent of the total primary MPCD effluent) by the waste oil pump rate (90 gpm) and multiplying by the number (three) of crewmembers.

$$\frac{12{,}810 \text{ gal}}{\text{yr}} \bullet \frac{\text{min}}{90 \text{ gal}} \bullet \frac{\text{hr}}{60 \text{ min}} \bullet \frac{3 \text{ hrs labor}}{\text{hr}} = 7.1 \text{ hrs labor/yr}$$

Maintenance tasks and frequency for a 50-gpm membrane system (prototype) are assumed to be the same as those for the prototype 10-gpm membrane units installed on DDG 51 Class vessels. However, because a 50-gpm system includes approximately five times as many membranes that require cleaning, the hours for certain tasks are assumed to be proportionately higher.

Annually, the membrane filtration system requires approximately 14.9 personnel hours of time-based maintenance, 5.9 personnel hours of condition-based maintenance within 12 nm, and 0 personnel hours of condition-based maintenance beyond 12 nm. Table 4-34 and Table 4-35 summarize the time-based maintenance and the condition-based maintenance requirements, respectively, for a membrane filtration system. Table 4-36 provides the annual labor hours required to operate and maintain the proposed MPCD discussed in this section.

Table 4-34. Membrane Filtration System Time-Based Maintenance Hours (LHD 1 Class)

Maintenance Activity	Maintenance Time (hours)	Frequency	Annualized Maintenance Time (hours)
Clean and inspect permeate flow sensor	0.2	3 months	0.8
Clean and inspect recirculation loop temperature sensor	0.2	3 months	0.8
Clean and inspect continuous level transducer	0.2	6 months	0.4
Clean and inspect high level sensor probe	0.2	6 months	0.4
Calibrate pressure gauges	5.0	12 months	5
Clean and inspect recirculation pump suction valve	1.8	12 months	1.8

Maintenance Activity	Maintenance Time (hours)	Frequency	Annualized Maintenance Time (hours)
Clean membranes (no MRC; for scheduling only. Perform CLEAN cycle. Perform quarterly and when membrane resistance is greater than 100% as indicated on the control panel)	0.5	3 months	2
Clean and inspect membrane system control panel	1.6	6 months	3.2
Inspect membrane system grounding straps	0.1	12 months	0.1
Perform lamp test of membrane system control panel; measure insulation resistance.	0.1	3 months	0.4
Total Annual Labor per unit	-	-	14.9
Total Annual Labor per vessel	-	-	14.9

Table 4-35. Membrane Filtration Condition-Based Maintenance Hours (LHD 1 Class)

Maintenance Activity	Maintenance Time (hours)	Frequency (based on hours of MPCD operation)	Annualized Maintenance Hours (based on 420 operation hours within 12 nm)	Annualized Maintenance Hours (based on 0 operation hours beyond 12 nm)
Replace membranes (performed shoreside)	3	2400	.53	0
Drain membrane system	1	100	4.2	0
Fill membrane system with water	1.0	500	.84	0
Replace feed pump mechanical seal. Inspect internal parts	2.5	10000	0.10	0
Replace recirculation pump mechanical seal. Inspect internal parts	5	10000	0.21	0
Total Annualized Hours	-	-	5.9	0

Table 4-36. Membrane Filtration Annual Labor Hours (LHD 1 Class)

	MPCD Option: Membrane Filtration
Operator Hours Within 12 nm	7.1
Operator Hours Beyond of 12 nm	0
Condition-based Maintenance Within 12 nm	5.9
Condition-based Maintenance Beyond 12 nm	0
Time-based Maintenance	14.9
Total Time	27.9

4.9.1.5 Consumables, Repair Parts, and Tools

On vessels equipped with the UF system, membranes are scheduled for replacement after approximately 2400 hours of use. During replacement, a new, clean set of membranes is installed in the UF system and the old, used ones are sent to shore to be cleaned. This regular maintenance does not require any consumables because the membranes are exchanged. Furthermore, UF systems do not require any unusual repair parts or tools.

4.9.1.6 Interface Requirements

Table 4-37 provides the UF system interface requirements.

Table 4-37. Membrane Filtration Interface Requirements (LHD 1 Class)

Shipboard System	Interface Requirement (50-gpm system)
Electric Power	35 kW (47 hp), 440 Volts/3 Phase/ 60Hz
Compressed Air	80 to 100 psi, 5 scfm (operate valve actuators)
Potable Water	Flush Sub-System: 10 gpm, 30 psi
Drainage	Concentrate from recirculation sub-system drains to WOT. When back flushing membranes, oily waste flushed from system is diverted to OWHT.

LHD 1 Class vessels are able to support these requirements with no significant impacts on existing systems.

4.9.1.7 Control System Requirements

The UF system operates automatically in response to the primary OWS. In addition, a UF unit installed on an LHD 1 Class vessel may be equipped with an OCM to measure the oil content of OWS effluent. If the OCM detects an oil concentration greater than the predetermined desired concentration, the OCM will redirect the effluent back to the OWHT to be processed again by the OWS and UF. The UF system does not have any unique control system requirements.

4.9.1.8 Other/Unique Characteristics

No other/unique characteristics have been identified with respect to this MPCD option.

4.9.2 Cost Analysis

The following cost data and calculations are provided to allow the reader to compare relative costs associated with using and installing the UF membrane MPCD on an LHD 1 Class vessel. Because of the extensive modifications required to install a UF system on the first three LHD 1 Class vessel's (LHD 1, 2, and 3), the costs presented in this analysis only apply to subsequent LHD 1 Class vessels.

4.9.2.1 Initial Cost

The UF system (i.e., one unit) procurement cost is $600,000 (Smith, 1999). Based on ship drawing analysis and an LHD 5 (an LHD 1 Class vessel) ship check, the Navy estimates that installation of a UF membrane on an LHD 1 Class vessel would cost $320,700 per vessel (Navy, 2000). Technical manuals cost approximately $85,000 ($12,140 per vessel) to develop a 150-page manual (Gallagher, 1999). The development of technical drawings will cost $61,820 ($8,832 per vessel). The cost for training materials is approximately $9,330 ($1,330 per vessel) (Smith, 2001). The total initial cost of a UF membrane system on an LHD 1 Class vessel is $943,000 per vessel.

4.9.2.2 Recurring Cost

This MPCD requires 27.9 personnel hours per year for operation, condition-based maintenance and time-based maintenance within 12 nm, as explained under Section 4.9.1.4. The number of annual labor hours multiplied by the $22.64 hourly MPCD operator labor rate produces the annual labor cost within 12 nm.

$$\frac{\$22.64}{\text{hr labor}} \bullet \frac{27.9\ \text{hrs labor}}{\text{yr}} = \$632/\text{yr (within 12 nm)}$$

The labor required to transfer waste oil generated by the gravity coalescence system to a disposal activity is included in the above labor cost estimates. As explained in Section 1.1.2, the disposal activity is assumed to dispose of the waste oil at no charge for Navy vessels.

Table 4-38 summarizes the annual recurring costs for a membrane filtration system on an LHD 1 Class vessel.

Table 4-38. Annual Recurring Costs for Membrane Filtration System (LHD 1 Class)

Vessel Operating Parameter	Disposal Cost Used	Annual Recurring Cost ($K)
Within 12 nm	Navy	.632
Beyond 12 nm	Navy	0

4.9.2.3 Total Ownership Cost (TOC)

Table 4-39 summarizes the TOC and annualized cost over a 15-year lifecycle for a UF membrane system on an LHD 1 Class vessel.

Table 4-39. TOC for Membrane Filtration System (LHD 1 Class)

Cost ($K)	Vessel Operation Within 12 nm	Vessel Operation Within + Beyond 12 nm
Total Initial	943	943
Total Recurring	7.00	7.00
TOC (15-yr lifecycle)	950	950
Annualized	81	81

4.9.3 Applicability of the Membrane Filtration Analysis to New Design Vessels

The practicability and operational impact of using UF membrane systems on new design vessels in this vessel group are expected to be similar to the impact on existing vessels in this group, as represented by LHD 1 Class vessels. The installation cost would be different for new design vessels, however all other costs are not expected to change. Therefore, except for the installation cost and the adjusted TOC, this new design analysis refers to Sections 4.9.1 and 4.9.2 for all other feasibility factors. As discussed in Section 1.2, to estimate the new design installation cost, a factor of 67 percent was applied to the UF membrane system cost estimate for existing vessels within this group. Using this factor, the assumed installation costs for the new design LHD 1 vessel group is $215,000, per vessel. The total projected initial cost for a UF membrane system aboard these new design vessels is $836,000, per vessel. Table 4-40 provides the costs for these new design vessels.

Table 4-40. TOC for UF Membrane System on New Design Vessels (LHD 1 Class)

Cost ($K)	Vessel Operation Within 12 nm	Vessel Operation Within + Beyond 12 nm
Total Initial	836	836
Total Recurring	7.00	7.00
TOC (15-yr lifecycle)	843	843
Annualized	72	72